ERDC/CERL TR-13-20

Construction Engineering Research Laboratory

US Army Corps of Engineers®
Engineer Research and Development Center

ERDC
INNOVATIVE SOLUTIONS for a safer, better world

DoD Corrosion Prevention and Control Program

Demonstration of Corrosion-Resistant Fire Hydrant Retrofits For Military Installations

Final Report on Project F09-AR12

Edgar Dean Smith, Mark D. Ginsberg, and Clint Wilson

October 2013

DoD Corrosion Prevention and Control Program
ERDC/CERL TR-13-20
October 2013

Demonstration of Corrosion-Resistant Fire Hydrant Retrofits For Military Installations

Final Report on Project F09-AR12

Edgar Dean Smith, Mark D. Ginsberg, and Clint Wilson

Construction Engineering Research Laboratory
US Army Engineer Research and Development Center
2902 Newmark Drive
Champaign, IL 61822

Final report

Prepared for US Army Corps of Engineers
Washington, DC 20314-1000

Under Project F09-AR12, "Demonstration of a New Generation of Corrosion-Resistant Fire Hydrant Retrofits at Major US Military Installation"

Abstract

Most fire hydrants are operated rarely, but it is critical that they be fully functional when needed. Corrosion can severely damage hydrants internally without any visible indications. Inoperable hydrants present an unacceptable risk to Department of Defense personnel and property. This project demonstrated a corrosion-resistant retrofit kit for fire hydrants that includes an anti-backflow valve to prevent accidental or intentional water-supply contamination. The technology was installed on 90 fire hydrants of various makes, models, and ages at Fort Leonard Wood, MO. To evaluate hydrant performance before and after the retrofits, the researchers measured the torque needed to operate each hydrant, volumetric flow, and static pressure. After 12 months in service with the retrofits, a subset of the hydrants was opened for visual inspection of the corrosion-resistant replacement parts. In addition, water chemistry at the demonstration site was tested three times within a year for corrosivity and scaling tendencies, and microscopic studies were performed on a previously failed hydrant component to determine the cause of its shape deformation.

Visual evaluation of DATV components after approximately 12 months of service indicated that they provide excellent corrosion resistance. An economic analysis of the demonstration indicated a return on investment of 5.73.

Contents

Figures and Tables

Figures

Tables

Preface

This demonstration was performed for the Office of the Secretary of Defense (OSD) under Department of Defense (DoD) Corrosion Control and Prevention Project F09-AR12, “Demonstration of a New Generation of Corrosion Resistant Fire Hydrant Retrofits at Major US Military Installation.” The proponent was the US Army Office of the Assistant Chief of Staff for Installation Management (ACSIM), and the stakeholder was the US Army Installation Management Command (IMCOM). The technical monitors were Daniel J. Dunmire (OUSD(AT&L)), Bernie Rodriguez (IMPW-FM), and Valerie D. Hines (DAIM-ODF).

The work was performed by the Materials and Structures Branch of the Facilities Division (CF-M), US Army Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL). The ERDC-CERL project managers were Dr. Edgar Smith and Mr. Mark Ginsberg. A portion of this work was performed by Christopher Olaes and Larry Clark of Mandaree Enterprise Corp. (MEC), Warner Robins, GA. The analysis documented in Appendix D was provided under contract to ERDC-CERL by Robert A. Weber. At the time this report was prepared, Vicki L. Van Blaricum was Chief, CEERD-CF-M; L. Michael Golish was Chief, CEERD-CF; and Kurt Kinnevan, CEERD-CV-T, was the Acting Technical Director for Adaptive and Resilient Installations. The Deputy Director of ERDC-CERL was Dr. Kirankumar Topudurti and the Director was Dr. Ilker Adiguzel.

The following installation personnel are gratefully acknowledged for their support and assistance in this project:

- Mr. Roy Bethel – Deputy Director of Public Works, Fort Leonard Wood, MO
- Mr. Keith Pendleton –Chief, Facility Maintenance Division, DPW, Fort Leonard Wood, MO
- Mr. Ralph Mills – Fort Leonard Wood Fire Department Chief, MO.

The Commander of ERDC was COL Jeffrey R. Eckstein, and the Director was Dr. Jeffery P. Holland.

Executive Summary

This project demonstrated the application of the corrosion-resistant Davidson Anti-Terrorism Valve (DATV) to fire hydrants in place at Fort Leonard Wood, MO. This technology is available as an off-the-shelf retrofit kit that requires no excavation and minimal installation time.

The primary objective of the application was to improve the performance of fire hydrants damaged by or susceptible to corrosion by upgrading stock internal components with high-quality stainless steel and brass replacement parts. The secondary objective of this demonstration was to reduce the risk of accidental or intentional introduction of contaminants into the Fort Leonard Wood water supply through a fire hydrant. The DATV supports both objectives: the retrofit kit is equipped with internal replacement components that are highly resistant to corrosion degradation, and it includes an anti-backflow valve that cannot readily be defeated due to operating errors or unobtrusive tampering.

DATVs were installed on 90 fire hydrants that have been in service approximately 3–50 years, with most having been installed before 1980. Six widely used hydrant makes and models were selected for the demonstration in order to assess the applicability of the DATV to types and makes of hydrants being commonly used at Department of Defense (DoD) facilities and installations. Eighty-two demonstration hydrants were upgraded with a standard DATV retrofit kit. Six of the hydrants—one of each make and model in the sample—received a DATV retrofit kit, but with a substituted higher-quality (i.e., more corrosion-resistant) stainless steel valve stem than the standard kit. The final two hydrants received a DATV kit, but with a cold-rolled steel valve stem of the quality typically supplied with a new fire hydrant.

The amount of force needed to operate each hydrant was measured before and immediately after the installation of each DATV kit. Measurements of water flow and static pressure were made at the same time. In addition, water was sampled approximately 6 and 12 months after kit installation for chemistry analysis. After 12 months in service, 12 hydrants were opened and inspected for signs of corrosion and other wear.

Results of the water chemistry analysis indicated that the pH is neutral and that there is little risk of scaling related to calcium in the water. A visual inspection of the DATV components in 12 hydrants was made after 12 months in service. The stainless steel components of the DATV kit showed no signs of corrosion damage. The one cold-rolled valve stem that was inspected after 12 months—original manufacturer's equipment experimentally substituted for the standard DATV stainless stem—was found to be severely corroded in two places. In Appendix D, it is shown that the corrosion of the original stems is caused by dissimilar metal corrosion between the brass raceway for the O-rings and the cold rolled steel stem underneath.

The overall results of this demonstration were highly successful. Before the demonstration, almost 25% of the fire hydrants were inoperable and another 16% had substandard performance characteristics that made them unsuitable for fire service. The DATV kits returned 100% of the hydrants back to a fully operational status while providing greatly improved corrosion resistance and backflow-prevention capabilities. The return-on-investment ratio for this project was calculated as 5.74 without any attempt to account for the indirect but critical value of improving fire safety and water-supply security for DoD assets.

Unit Conversion Factors

Multiply	By	To Obtain
degrees Fahrenheit	(F-32)/1.8	degrees Celsius
feet	0.3048	meters
gallons (US liquid)	3.785412 E-03	cubic meters
inches	0.0254	meters
mils	0.0254	millimeters
square feet	0.09290304	square meters

1 Introduction

1.1 Problem statement

The US Army Installation Management Command (IMCOM) and the Army Chief of Staff for Installation Management (ACSIM) consider firefighting capability to be a critical priority. Firefighters rely on a network of fire hydrants to provide adequate fire protection to an installation's residential communities, industrial facilities, and administrative offices. Many hydrants are installed throughout protection areas for ready access by firefighters, but rapid response also requires that hydrants operate as designed.

The basic design of fire hydrants has not changed over decades, and most of those now in service include an operating valve fabricated of cold-rolled steel, which is highly susceptible to corrosion. Hydrants that appear to be functional from the outside can in fact be corroded to the point of inoperability. Hydrants locked shut by corrosion are unavailable to fight a fire, and are therefore an unacceptable risk on military installations.

Fire hydrants must be maintained at or restored to full functionality. Many hydrants fail due to valve stem corrosion. A corrosion-resistant technology that extends hydrant service life, ensures functionality on demand, and reduces life-cycle costs would be highly desirable to Department of Defense (DoD) installation management personnel.

Another potential operational problem relates to fire hydrant security. Hydrants must be secure against vandalism, tampering, and deliberate attacks intended to harm the installation water supply. Most hydrants are located in openly accessible areas, and are vulnerable to tampering or unauthorized operation. Not only can intentional hydrant damage jeopardize installation fire protection, but hydrants also can provide an adversary an access port into a community's potable water system, which typically uses the same pipes as the fire-protection water supply. The contamination risk from a backflow-type attack or accident is outlined in a report by the Environmental Protection Agency (EPA 2011). Security technology can mitigate such risks, but conventional water-system security components such as locks or cages slow the operation of hydrants and cannot be used without delaying response time.

A fire hydrant retrofit technology, developed by Davidson Hydrant Technologies (Davidson 2013), was selected for demonstration as a potential solution to address the problems of cost-effective fire hydrant refurbishment, resistance to dissimilar-metals corrosion, and prevention of accidental or intentional backflow contamination of potable water supplies. The product selected is called the Davidson Anti-Terrorism Valve, which is an off-the-shelf retrofit kit with upgraded corrosion-resistant components of stainless steel and brass. The device consists of a spring-loaded backflow-prevention valve that does not alter the external appearance of the hydrant, and no excavation is required to install it. A hydrant equipped with a DATV operates using the same type of wrench and action as any standard fire hydrant.

1.2 Objective

The objective of this project was to identify 90 fire hydrants at a major Army installation needing to be refurbished, retrofit them with the Davis Anti-Terrorism Valve (DATV), and assess the results.

1.3 Approach

The site selected for this demonstration was Fort Leonard Wood (FLW), MO. The US Army Engineer Research and Development Center (ERDC-CERL) coordinated with the FLW Fire Department and Directorate of Public Works (DPW) to select the specific hydrants to be retrofit. Ninety fire hydrants of several different makes and models located in critical protection areas were identified for the demonstration. A preliminary onsite meeting at the installation included project team members from ERDC-CERL, the FLW DPW, the contractor, and the vendor. The team surveyed hydrants throughout the base that would be most suitable to assess the usability of the DATV on a variety of hydrant models and types.

The performance characteristics of each selected fire hydrant were measured before installing a DATV kit. Each hydrant was fitted with a DATV kit and other minor modifications, including a breakaway capability for older hydrants not so designed. Upon completing the installation, performance measurements were then made and documented for analysis.

On eight of the 90 hydrants, the demonstration also included removal, replacement, and examination of the hydrant stems. This was done to assess the corrosion performance of the 304 stainless steel shafts, and to compare the performance of 304 stainless to both 316 stainless and to a non-stainless, cold-rolled steel shaft.

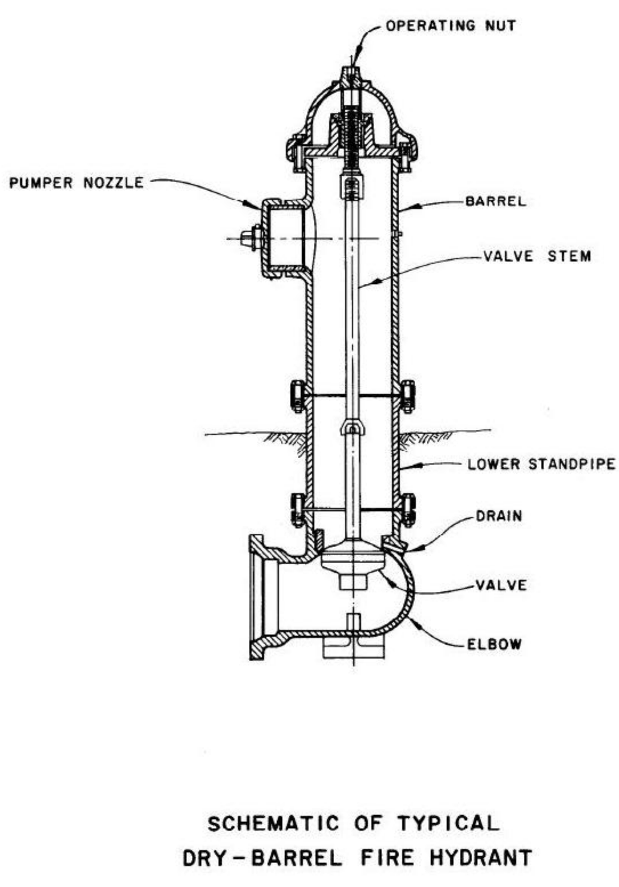
Water samples were taken at the hydrant during the retrofit process and at 6 and 12 months after the retrofit was completed. The water samples were sent to a laboratory for a chemical analysis. The analysis results were used to assess corrosivity potential to hydrant components.

2 Technical Investigation

2.1 Overview

FLW has approximately 1,100 fire hydrants of six different makes and many different models throughout the installation. The operational mechanics of all the hydrants are similar, however, with little variation. The two basic types of fire hydrant are *dry barrel* and *wet barrel* (the barrel being the visible vertical “cylinder” of the hydrant). The main difference between the types is that the dry-barrel hydrant is empty when the valve at the foot of it is closed while the wet-barrel hydrant remains full. Dry-barrel hydrants are the predominant type used on US military installations, except in southern California. All of the FLW’s hydrants are the dry-barrel type, but the DATV is available for both types. A typical dry-barrel hydrant design is shown in Figure 1.

Figure 1. Cross-sectional illustration of a typical dry-barrel hydrant.
(Source: TM 5-813/AFM 88-10, vol 5.)



The hydrant models included in this demonstration included the Mueller Standard, Mueller INS, Mueller Centurion, American Foundry, Clow Medallion, and Kennedy K10. Before installing the DATV kit, hydrant performance characteristics were measured, including the force (torque) needed to open the hydrant, volumetric flow, and static water pressure. After the kit was installed, measurements of the same parameters were taken and recorded. Figure 2 shows volumetric flow-performance testing, and Figure 3 shows both torque and static pressure testing.

Figure 2. Volumetric flow test.

Figure 3. Torque and static pressure test.

The DATV kit includes a stainless steel stem, a brass valve, a stainless steel spring, a steel barrel sleeve coated with ethylene-propylene-diene-monomer (EPDM), and two gaskets and o-rings. Figure 4 shows the main components. Appendix A includes DATV technical specifications incorporated into the contract language for this demonstration. One example of each of the six hydrant models was fitted with a 316 stainless steel stem for evaluation, and all but two of the remaining hydrants were fitted with the 304 stainless steel stems that are standard with the DATV kit. The final two hydrants were designated as experimental controls, and each was fitted with a new standard cold-rolled steel stem. This project also included replacing 25 brass operating and hold-down nuts (Figure 5) found to be in the poorest condition. More details about hydrant models and materials used can be found in Appendix B.

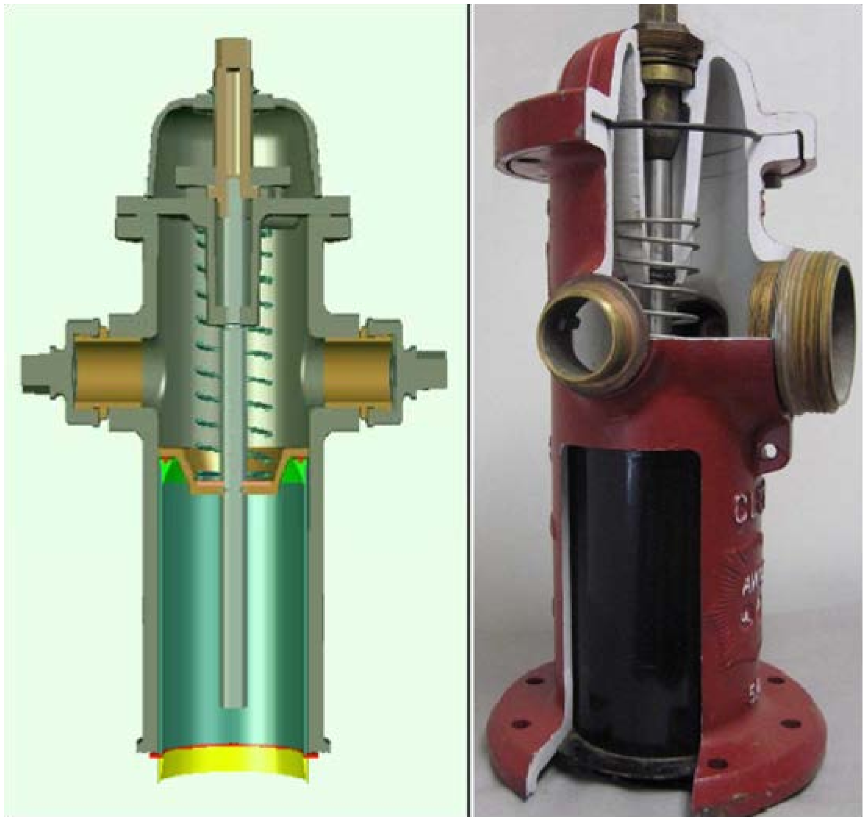
Figure 4. DATV stainless steel stem, brass valve, stainless steel spring, and barrel sleeve separately (left) and mocked up as assembled (right).

Figure 5. Brass operating nut.

2.2 Installing the technology

Once the performance measurements were taken, the upper barrel of the hydrant was disassembled. Any foreign materials or corrosion that may have accumulated on the barrel flange inner surfaces was mechanically removed using a wire wheel to provide a clean surface for gaskets to be installed. The hydrant operating nut and the hold-down nut were inspected for damage, cleaned, and lubricated. The old hydrant stem was removed and replaced with the stainless steel stem. Before the barrel was placed back on the hydrant, DATV barrel sleeve was positioned on the hydrant with gaskets on both sides of the sleeve flange (Figure 6). The top of the sleeve is machined to hold an elastomeric quad ring, which seals the surface area for the brass valve to sit on. The brass valve slides onto the hydrant stem and rests on the barrel sleeve. An o-ring is seated in the valve and is compressed with the stem. A stainless steel spring is placed around the stem on top of the brass valve and the hydrant is reassembled. Standard lubricating procedures were followed during reassembly using industry-approved food-grade grease.

Figure 6. Cutaway illustration of installed DATV kit.

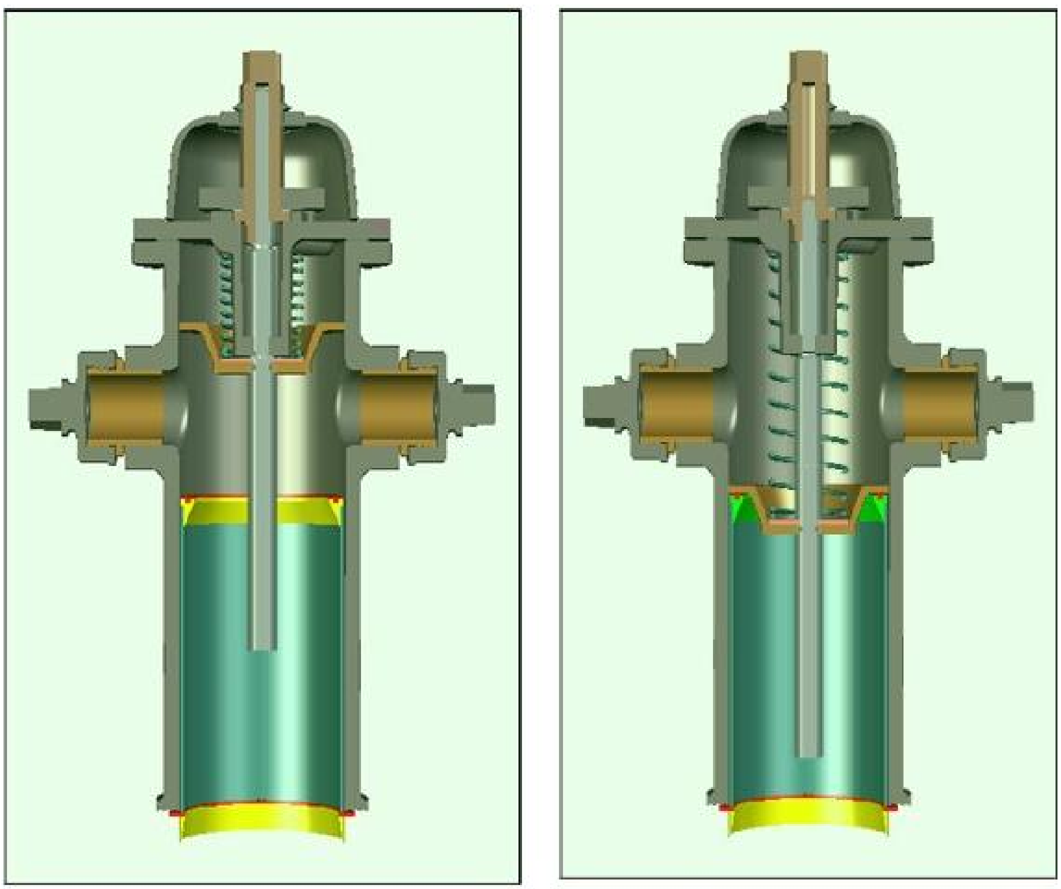


The average time to disassemble a properly maintained hydrant by an experienced technician is 5–10 minutes. However, many hydrants were in a severely corroded condition and took as long as 60 minutes to disassemble. These hydrants needed over 250 ft-lb of torque to turn the operating nut, which required the strength of three men using a “cheater bar” to extend the wrench handle for extra leverage. Hydrants needing more than 250 ft-lb of torque to open were considered inoperable. The flange bolts of several inoperable hydrants had to be sheared off or cut off because they were too corroded to remove with a wrench. Many hold-down nuts were also seized and difficult to remove. Consequently, cheater bars and as many as three people were also needed to remove these nuts.

In some of these cases a torch had to be used to heat and loosen the nuts. In many cases, the ends of seized operating nuts had been rounded off when the fire department tried to use them. Typical field improvisations were applied to remove the rounded nuts, including mechanical flattening of nut faces, use of a pipe wrench, and heating with a torch. New hold-down nuts and operating nuts were used for the hydrants in the worst conditions.

When the hydrant is in the closed position, the spring applies downward pressure to the brass valve against the barrel sleeve. The elastomeric quad ring creates a seal between the barrel and the valve. When the hydrant is opened, the water pressure pushes against the valve and compresses the spring, opening flow to the nozzles. When the hydrant shutoff valve is closed, the internal water pressure drops to zero, freeing the spring to de-compress and close the brass backflow-prevention valve. There is a 1/16 in. annular gap between the outer surface of the sleeve and the inner surface of the hydrant barrel. A one-way check valve on the sleeve allows water to drain from the upper barrel and out the weep holes in the lower barrel of the hydrant to prevent freezing damage. The anti-backflow valve motion of typical DATV kit is pictured in Figure 7.

Figure 7. DATV anti-backflow valve positions during water flow (left) and at rest (right).



Current fire hydrant design includes several breakaway features that are intended to prevent a hydrant from opening in the case of a collision with the barrel. However, many hydrants on the installation are so old that they weren't manufactured with modern breakaway design. Older hydrants had a two-piece barrel design, with the bottom and top halves bolted together. Most of these hydrants are fitted with a sacrificial flange or shear bolts at this connection, but they were not specifically designed to fail on impact to avoid breaking the lower barrel attached to the water main. They also have a one-piece stem without a shear coupling. Older hydrants without adequate breakaway features were fitted with them as was necessary.

The older hydrants have a single solid stem connected to the hydrant valve at the water main and running up to the operating nut. Modern designs separate the stem into two pieces pinned to a breakaway coupler. The couplers are located at the base of the upper barrel at the breakaway flange. The DATV kits include an upper stainless steel stem that connects to the breakaway coupling. A simple modification was made to the single-stem hydrants to adapt them to the DATV kit. A special tool was installed that marked the cut point for the stem and provided a drill jig and guide for drilling the stem for a breakaway coupler. Installation of the breakaway couple is shown in Figure 8 – Figure 12.

Figure 8. Cutting the solid stem.

Figure 9. Drilling hole for coupler mount.

Figure 10. Breakaway coupler.

Figure 11. Breakaway coupler attached to stainless steel stem.

Figure 12. View of installed DATV kit sleeve and stem in barrel.

2.3 Operation and monitoring

Water samples were taken during installation and 6 and 12 months afterward. The water samples were sent to a laboratory for chemical analysis.

A performance evaluation was conducted approximately 12 months after the installation of the DATV kits. The components were visually inspected for general wear and corrosion. One 304 stainless steel stem was removed and replaced from one example of each of the six hydrant models included in the study. An additional 316 stainless steel stem from a Mueller Centurion hydrant and a cold rolled stem from the Mueller Standard control hydrant were removed and replaced. The DATV parts were visually inspected to assess their corrosion resistance. Table 1 lists the evaluated hydrants and their locations. Appendix B has a complete list of the demonstration hydrants with technical details.

Table 1. Hydrants evaluated after 12 months of exposure.

Hydrant No.	Physical Location	Make/Model	Stem Material
4000/43	Elem. School	Mueller Standard	(Water Sample)
4000/55	4238-B Thayer	Mueller Standard	Cold Rolled
4000/88	Sturgis St.	Mueller Standard	304SS
4000/86	4110 Piney Hills Dr.	American Foundry	304SS
0300/02	310 Missouri Ave.	American Foundry	304SS
2300/19	2310 Railroad St.	Kennedy K10	304SS
2300/20	2311 Railroad St.	Mueller Centurion	316SS

2300/03	2350 Louisiana St.	Mueller Centurion	304SS
1700/08	Bldg 1714	Mueller INS	304SS
1700/18	Bldg 1740	Mueller INS	304SS
1700/12	1734 Michigan Ave.	Clow Medallion	304SS

3 Discussion

3.1 Metrics

Installation water samples were collected for chemical analysis. The inductively coupled plasma (ICP) analyses were performed by an independent laboratory, Applied Technical Services in accordance with ASTM E1479-99 (2005). Other lab tests such as pH and Alkalinity were performed by Applied Technical Services according to Standard Methods (APHA 1976)

The Langelier Saturation Index (LSI) was used to indicate the potential for scaling from the water supply. The LSI is an equilibrium index that uses the thermodynamic driving force for calcium carbonate scale formation and growth. The index does not indicate how much scale or calcium carbonate will actually precipitate to bring water to equilibrium. The LSI is derived as the difference in pH between observed conditions and at calcium carbonate saturation. The total alkalinity (mg/l as $CaCO_3$), the calcium hardness (mg/l Ca^{2+} as $CaCO_3$), the total dissolved solids (TDS) in mg/l, the actual pH, and the temperature of the water (°C) are used to solve for the LSI. In the case of this project, TDS value is unknown, but it can be estimated using the conversion table in Appendix C. The LSI is defined as

$$\text{LSI} = \text{pH} - \text{pHs} \tag{1}$$

where

pH = the measured water pH
pHs = the pH at saturation in calcite or calcium carbonate, which is defined as:

$$\text{pH}_s = (9.3 + A + B) - (C + D) \tag{2}$$

where

$A = (\text{Log}_{10}\,[\text{TDS}] - 1) / 10$
$B = -13.12 \times \text{Log}_{10}\,({}^{o}\text{C} + 273) + 34.55$
$C = \text{Log}_{10}\,[Ca^{2+} \text{ as } CaCO_3] - 0.4$
$D = \text{Log}_{10}\,[\text{alkalinity as } CaCO_3]$.

3.2 Results

The installation of 90 retrofits began on 22 March 2010 and was completed 9 April 2010. Individual installation work sheets were used to document the results of tests performed and conditions of hydrants before and after retrofit. The results are summarized below.

3.2.1 Torque measurements

These measurements were recorded before and after the installation of the DATV kits. The ideal torque required for an individual person to open a hydrant is 30–45 ft-lb. A hydrant was classified as inoperable if it required more than 250 ft-lb of torque to open. Although hydrants requiring less than 250 ft-lb were considered operable, hydrants needing more than 150 ft-lb of torque required the extra leverage provided by a cheater bar to operate. As previously noted, in most cases it required two or three people pressing applying force to a cheater bar to open an inoperable hydrant for servicing. Figure 13–Figure 15 illustrate the torque characteristics of the 90 hydrants evaluated.

Figure 13. Torque needed to open each of the 90 fire hydrants before installing DATV kits.

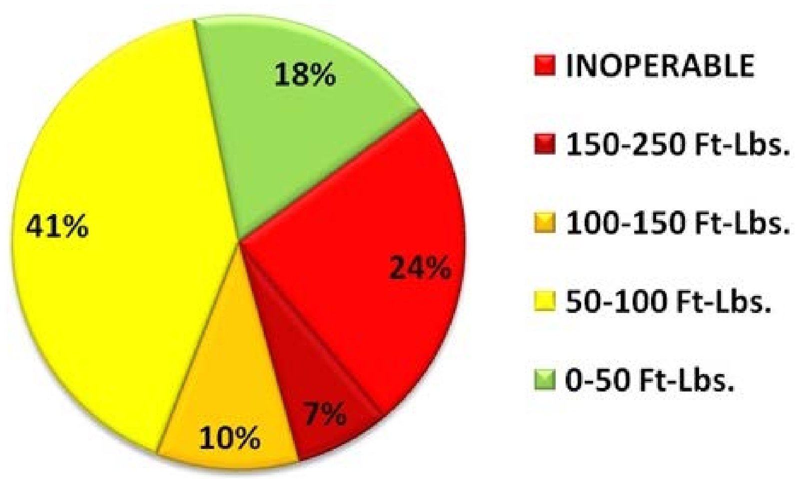


Figure 14. Torque needed to open each of the 90 fire hydrants after installing DATV kits.

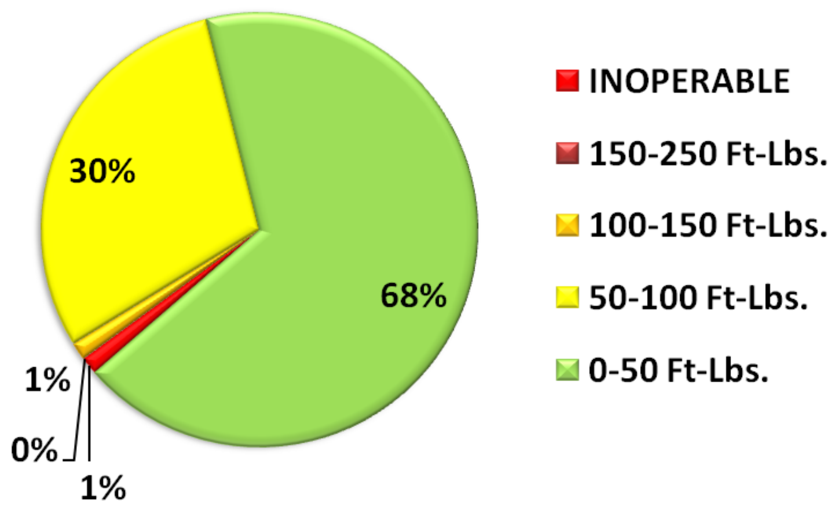
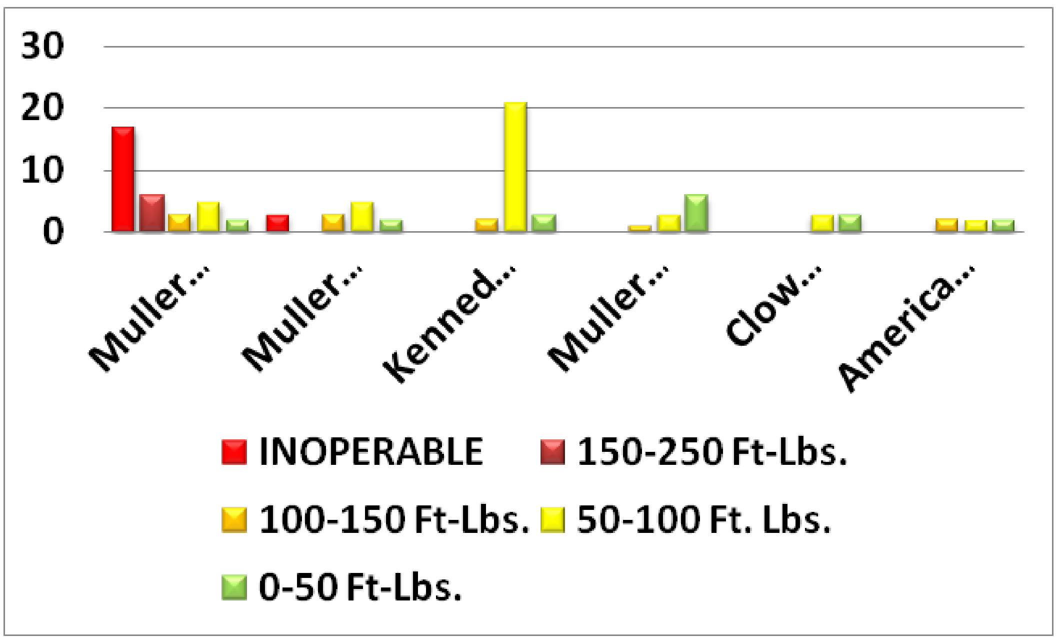


Figure 15. Torque needed to open each hydrant models before installing a DATV kit.



3.2.2 Flow and static pressure measurements

The DATV kits are designed not to restrict any flow from the hydrants. In most cases, the shape of the barrel sleeve will reduce turbulent flow through the barrel and increase the flow rate. Upon completion of the DATV installation, all inoperable hydrants were returned to an operable status. The results are shown in Figure 16 and Figure 17. Static pressure was also recorded; as expected, it did not change with the installation of the DATV kits.

Figure 16. Volumetric flow through each hydrant model before installing a DATV kit.

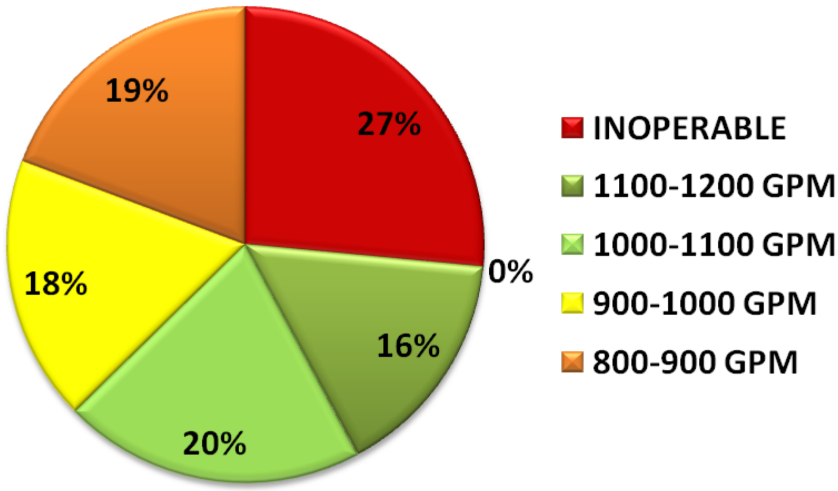
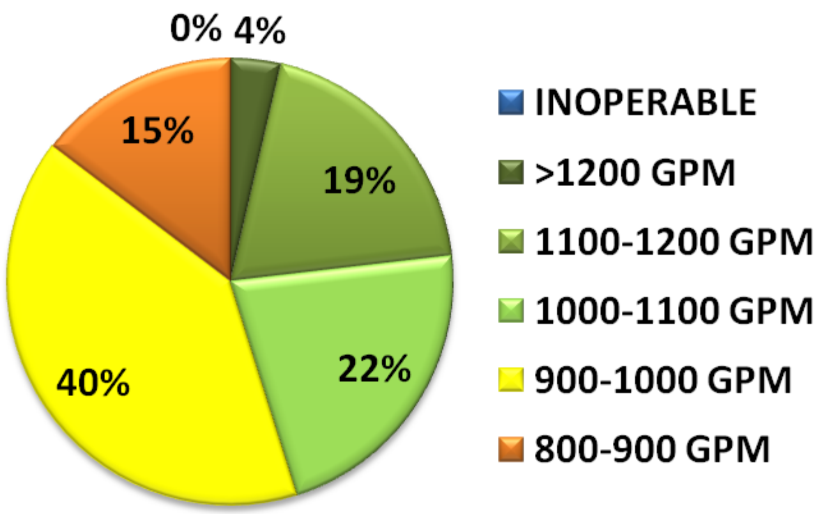


Figure 17. Volumetric flow through each hydrant model after installing a DATV kit.



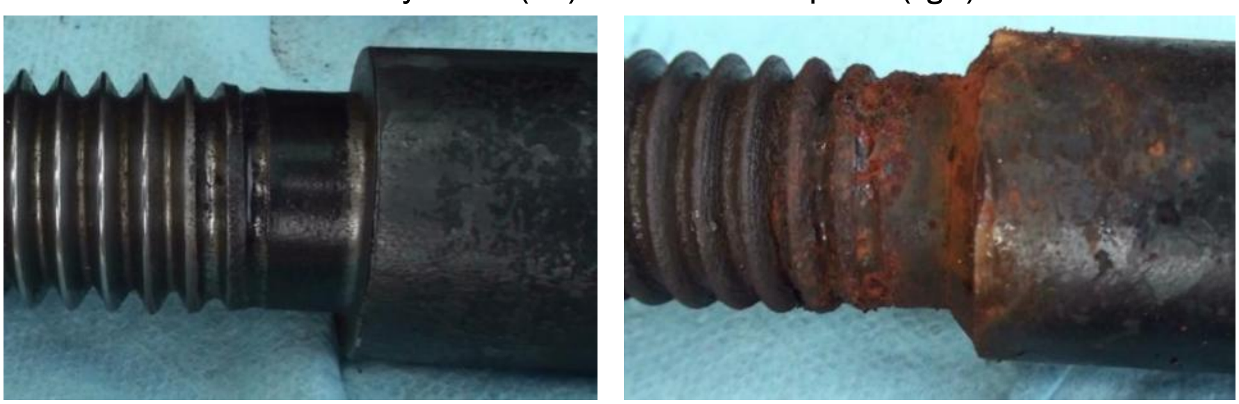
3.2.3 Twelve-month visual inspection

Table 1 (page 12) lists the hydrants inspected after 12 months of use with the DATV retrofits. At that time, various components were inspected or retrieved from the selected hydrants as described in section 2.3.

After 12 months of exposure, none of the inspected stainless steel stems showed any signs of corrosion. Ferrous oxide residue from the lower stem and the bonnet had discolored the stainless steel stem in two places (Figure 18). The cold-rolled stem was severely corroded at the bottom of the threaded area and the bottom of the stem (Figure 19). The top of the threaded area was protected inside the oil reservoir. The remainder of the stem is protected by the phosphate coating from the manufacturer, but the coating has begun to fail at the thread transition to the solid surface. As a result, lateral undercutting corrosion and blistering has caused the loss of adhesion between the paint and the metal substrate. Further corrosion of the cold rolled stem is expected over time.

Figure 18. DATV 304 stainless steel stem designed by DATV for a Mueller Standard hydrant after 12 months of exposure (top) and no exposure (bottom).

Figure 19. Cold-rolled stem design as supplied by manufacturer (Mueller Standard) with zero days of use (left) and 12 months exposure (right).



Most of the inspected DATV parts were in excellent condition after 12 months of use. However, severe corrosion was found on many bolts that hold the upper barrel to the lower barrel. Such corrosion is normal with the breakaway bolts supplied by a hydrant's manufacturer and is unrelated to the DATV kit. Figure 20 shows two examples of corrosion on breakaway bolts that were removed from service after 12 months of operation.

Figure 20. Corrosion on breakaway bolts 12 months after installation.

3.2.4 Water chemistry analysis

Water samples were taken during the installation of the DATV kits, and at approximately 6 and 12 months after installation. The LSI values (see section 3.1) for the samples taken on all three occasions were negative. This result indicates that the water will dissolve calcium carbonate and has little potential to scale. Individual calculations and results are shown in Appendix C.

3.3 Lessons learned

The DATV kits can be installed by a qualified crew in 30–40 minutes. However, if the hydrant is inoperable due to damage or corrosion, installation and maintenance time can increase to 2 hours. Figure 21 and Figure 22 depict the additional efforts required to service a inoperable hydrants in the course of this demonstration.

It is imperative that installers be trained and certified for DATV retrofit installation for all types of hydrant in place on the installation. Trained installers will be able to avoid errors during installation and will recognize corrosion problems developing in the hydrant soon enough for remedial measures to be effective. Also, trained installers can ensure proper operation of the anti-backflow valve to support site water security.

Figure 21. Three men using a 3 foot cheater bar and a pipe wrench to open inoperable fire hydrant.

Figure 22. Fire hydrant bolts being cut off due to seizing from corrosion.

During installation of the DATV kits, several hydrants were found with standing water in the barrel. This was caused by clogging of the weep/drain holes included in the lower barrel of the original hydrant. The weep holes allow water to drain from the barrel after the hydrant is closed.

Water trapped in a barrel can freeze and damage hydrant components. Figure 23 and Figure 24 show cracking and bulging of a brass operating nut caused by water freezing (see Appendix D for analysis). This kind of damage can interfere with hydrant operation. The barrel sleeve included in the DATV kits has a check valve to allow water to drain from the upper barrel, but if the weep holes are clogged, the barrel will not drain.

Figure 23. Operating nut sleeve* showing cracks due to freezing water trapped inside the barrel.

Figure 24. Bulge in operating nut sleeve.

* The report in Appendix D calls the hollow portion of the operating nut a "sleeve" or "copper sleeve." The operating nut/copper sleeve threads with the valve stem. It should not be confused with the DATV barrel sleeve, which is discussed throughout the body of this report.

4 Economic Summary

4.1 Costs and assumptions

The total demonstration project costs, broken into general categories, are shown in Table 2.

Table 2. Total demonstration project costs by category.

Item	Costs ($K)
Labor	180
Materials	215
Other direct costs	35
Total	430

A standard DATV kit with a 304 stainless steel stem costs $472, and installation costs $125. General maintenance tasks such has lubrication and flushing remain the same with the DATV kits installed, so the maintenance calculations are nullified from the total projected return on investment (ROI). However, unlike standard hydrants, one retrofitted with a DATV kit will continue to operate with substandard maintenance due to the corrosion-resistant kit components. The annual cost to maintain a hydrant, including materials, labor, and overhead, is $225 per hydrant. The annual cost to maintain 90 hydrants, therefore, is $20,250.

It is standard practice by installation fire departments to replace an entire hydrant assembly upon discovering an inoperable hydrant. Inoperable hydrants found were 35–50 years old. Approximately 23% of the hydrants were inoperable before retrofitting, with an additional 18% within 10 years of reaching replacement age. The cost to replace a hydrant has increased to $5,000. In many cases, the installation of a DATV kit will make it unnecessary to replace the entire hydrant.

Other backflow-prevention devices are labor-intensive to install, require extensive digging, require additional maintenance, and are not available for testing or servicing without excavation. The size of the pipe is the driving factor for the initial cost of any type of backflow-prevention device. A double check valve assembly can cost up to $2,000 for an 8 in. diameter unit.

There are several intangible benefits to the DATV kits that provide high value. Inoperable fire hydrants reduce firefighting capabilities, and the end result can be the failure to prevent catastrophic damage and loss of life. In one reported incident, firefighters were unable to extinguish a fire at an apartment complex in Woodlawn, OH, on 7 February 2011. Four nearby fire hydrants operated at a severely decreased capacity or not at all. The damage was estimated at $1 million, but no lives were lost (Kypost.com 2011). According to the US Fire Administration, the national death rate across the United States in 2007 was 13.2 per 1 million population, and the death rate in Washington, DC, alone was 39.2 per 1 million population. The total estimated cost for damages due to fire-related incidents was $10.4 billion in 2007.

Another intangible benefit of the DATV kit is the prevention of accidental or deliberate release of contaminants into a community water supply through a hydrant. Fire hydrant spacing in commercial and residential areas is typically about 500 feet, which provides an abundance of potential access to the potable water supply. A June 2011 contamination incident in Somerset, MA, was caused by accidental backflow from a lawn-care truck, resulting in an interruption of potable water availability. The US Army Soldier and Biological Chemical Command (SBCCOM) has identified several potent, readily available chemicals that are toxic to humans in concentrations as low as 1/20 of a quart to 1 million gal. of water—equivalent to the amount of water in a 6 in. water main 129 miles long. Such chemicals represent an available and portable threat that can be thwarted by properly designed and installed backflow-prevention valves.

4.2 Projected return on investment (ROI)

Alternative 1: Without applying the demonstrated technology, Fort Leonard Wood would need to replace the 21 identified inoperable hydrants at a cost of $5,000 each. Additionally, in order to make a valid comparison between the two cost scenarios here, it is necessary to include backflow-prevention capability in Alternative 1 because the DATV kit (Alternative 2) provides that in addition to corrosion resistance. Doing this makes hydrant technical performance equivalent under both scenarios, so the ROI analysis then addresses only the corrosion impacts and costs of the DATV kit. Providing backflow protection for the 90 hydrants in this demonstration would cost $2,000 per hydrant. The initial total cost during Year 1, including $225 maintenance cost per hydrant, is $305,250. Sixteen additional hydrants showed severe signs of corrosion and operational problems making them unsuitable for fire service. These hydrants were expected to need replacement within 10 years. The total cost for their replacement and maintenance for Year 10 is $100,250.

Alternative 2: The components of a DATV kit have an expected service life in excess of 30 years. The cost of upgrading a hydrant with a DATV kit is less than $650. Over 30 years, it is reasonable to assume that several fires may occur on any given installation. It is also reasonable, possibly conservative, to assume that six of these fires may not be adequately controlled because nearby fire hydrants may be corroded to inoperability. One can further assume that each of these six fires may cause $1 million worth of damage, similar to the Woodlawn, OH, fire cited above.

Using methods from the US Office of Management and Budget (OMB) Circular No. A-94, the ROI for Alternative 2 is 5.73. Table 3 shows the calculation.

Table 3. ROI calculation for Alternative 2.

Return on Investment Calculation

Investment Required			430,000
Return on Investment Ratio	5.73	Percent	573%
Net Present Value of Costs and Benefits/Savings	251,276	2,716,001	2,464,725

A Future Year	B Baseline Costs	C Baseline Benefits/Savings	D New System Costs	E New System Benefits/Savings	F Present Value of Costs	G Present Value of Savings	H Total Present Value		
1	305,250		20,250		18,926	285,287	266,361	285,000	0.9346
2	20,250		20,250		17,686	17,686			0.8734
3	20,250		20,250		16,530	16,530			0.8163
4	20,250		20,250		15,449	15,449			0.7629
5	20,250		20,250	1,000,000	14,438	727,438	713,000	1,000,000	0.7130
6	20,250		20,250		13,493	13,493			0.6663
7	20,250		20,250		12,610	12,610			0.6227
8	20,250		20,250		11,786	11,786			0.5820
9	20,250		20,250		11,014	11,014			0.5439
10	100,250		20,250	1,000,000	10,293	559,257	548,964	1,080,000	0.5083
11	20,250		20,250		9,621	9,621			0.4751
12	20,250		20,250		8,991	8,991			0.4440
13	20,250		20,250		8,404	8,404			0.4150
14	20,250		20,250		7,853	7,853			0.3878
15	20,250		20,250	1,000,000	7,339	369,739	362,400	1,000,000	0.3624
16	20,250		20,250		6,859	6,859			0.3387
17	20,250		20,250		6,411	6,411			0.3166
18	20,250		20,250		5,992	5,992			0.2959
19	20,250		20,250		5,599	5,599			0.2765
20	20,250		20,250	1,000,000	5,233	263,633	258,400	1,000,000	0.2584
21	20,250		20,250		4,890	4,890			0.2415
22	20,250		20,250		4,570	4,570			0.2257
23	20,250		20,250		4,271	4,271			0.2109
24	20,250		20,250		3,991	3,991			0.1971
25	20,250		20,250	1,000,000	3,730	187,930	184,200	1,000,000	0.1842
26	20,250		20,250		3,487	3,487			0.1722
27	20,250		20,250		3,258	3,258			0.1609
28	20,250		20,250		3,046	3,046			0.1504
29	20,250		20,250		2,847	2,847			0.1406
30	20,250		20,250	1,000,000	2,661	134,061	131,400	1,000,000	0.1314

5 Conclusions and Recommendations

5.1 Conclusions

This project demonstrated the Davidson Anti-Terrorism Valve (DATV), an off-the-shelf fire hydrant retrofit kit with critical components made of stainless steel and brass to dramatically reduce corrosion-related degradation. Specifically, the kit includes operating nuts and other hardware to replace the lower-grade steel components on stock fire hydrants that are highly susceptible to dissimilar-metals corrosion and other shortcomings in hydrant design that can lead to early hydrant failure. One corrosion-resistant component of the kit is an anti-backflow valve that prevents the accidental or intentional introduction of contaminants to the installation water supply through a hydrant. Hydrants equipped with a DATV operate using the same type of wrench and action as a standard fire hydrant, but the corrosion-resistant operating components ensure access on demand by firefighters without delay or excessive physical effort.

Analysis of DATV retrofit components after approximately 12 months of service indicated that they have excellent corrosion resistance. One of the manufacturer's stock cold-rolled valve stems that was experimentally substituted for the standard DATV stainless stem was inspected at the end of the test period and found to have areas of serious corrosion. Hydrants inoperable due to requiring excess force were eliminated from the demonstration sample, and almost 70 percent of the demonstration hydrants could be opened using less than 50 ft-lb of torque, which is ideal for operation by one person. These results should result in improved hydrant performance, better serviceability, and reduced life-cycle cost/total cost of ownership.

An economic analysis of the costs and benefits of this technology demonstration indicated a return on investment of 5.73. A significant but non-tangible benefit of the DATV backflow-prevention valve is the securing of the installation's water supply from accidental or intentional contamination through a fire hydrant.

5.2 Recommendations

5.2.1 Applicability

The corrosion resistance and anti-backflow features of this fire hydrant retrofit technology would be applicable and beneficial for any military installation, complex, campus, or community. The results of this demonstration indicate that the technology can be expected to drastically reduce severe component-corrosion problems that lead to inoperable hydrants assuming that good maintenance practices are followed. The technology's anti-backflow valve also helps to assure water-supply security in unrestricted areas that are not under continual observation.

5.2.2 Implementation

DoD implementation of this technology could be facilitated by appropriate revisions to the following standards and criteria documents:

1. AWWA C-502 for hydrant flow and head loss
2. NFPA 24: Standard for the Installation of Private Fire Service Mains and Their Appurtenances, 2010 Edition
3. UFC 3-600-01 Fire Protection Engineering for Facilities (2006) Unified Facilities Criteria (UFC) Fire Protection
4. United Facilities Guide Specifications (UFGS) UFGS 33 11 00 Water Distribution (Utilities), March 2006.

Draft text for recommended revisions is presented in Appendix E.

References

American (American Cast Iron Pipe Company). "Product Alerts." http://www.acipco.com/product_alerts.

American Flow Control. "American Flow Control Hydrant Upper Stem Replacement." http://www.mfmaonline.com/pub/Hydrant_recall_517132904.pdf.

American Public Health Association. 1976. Standard Methods for the Examination of Water and Wastewater, 14ed. Washington, DC: American Public Health Association.

ASTM E1479-99(2005). Standard Practice for Describing and Specifying Inductively-Coupled Plasma Atomic Emission Spectrometers. West Conshohocken, PA: ASTM International.

Circular No. A-94. 29. Oct. 1992. Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs. Washington, DC: Office of Management and Budget.

Clow Valve Company. "Product Notice for Medallion and F2500 Fire Hydrants." http://www.clowvalve.com/stem_replacement/safetynotice.php.

Davidson Hydrant Technologies. 2013. Company website. Accessed 9 May. http://davidsonhydrant.com/.

Environmental Protection Agency. 2011. "Security Product Guide: Fire Hydrant Security Devices." Accessed 30 June. http://cfpub.epa.gov/safewater/watersecurity/guide/productguide.cfm?page=firehydrantsecuritydevices.

"Fire Sustains After Hydrants Fail." 21 February 2011. Kypost.com, accessed 4 June 2013, http://www.kypost.com/dpps/news/local_news/Fire-sustains-after-hydrants-fail-_6102782 .

Roberge, P. 2008. *Corrosion Engineering: Principles and Practice*. New York: The McGraw-Hill Companies, Inc.

Technical Manual TM 5-813-5/Air Force Manual 88-10, vol 5. "Water Supply, Water Distribution." Washington, DC: Headquarters, US Army.

US Fire Administration. "Fire Statistics." http://www.usfa.dhs.gov/statistics/.

Appendix A: DATV Component Specifications from Project Contract Language

General

The specifications for the device shall consist of four main parts; insert seat, valve, stainless-steel stem and a stainless-steel spring. When retrofitted the stealth device shall be effective in preventing contamination of the water system either from back-flowing under pressure or contamination by siphoning into the water main. The retrofitted device shall be equally effective at preventing hydrant vandalism, i.e., placement of foreign objects such as rocks, bottles, silt or tennis balls into the hydrant which could clog fire engine pumper screens or damage the impeller blades. The device, when retrofitted, must be stealth and passive requiring no action on the part of the fire department other than that normally required to activate the hydrant. The device, when retrofitted, shall be maintenance-free and expose potable water to no new materials other than those currently approved for use in fire hydrants. The device shall withstand a backpressure of 350 psi without allowing an agent to enter the system.

Stainless-steel stem

The stem component of the device shall be made of machined 304 stainless steel and shall be a diameter and length which is compatible with the stem it replaces. The stem shall have left or right-hand threads as required by the hydrant bonnet into which it is retrofitted. Accommodations for traffic connections shall be provided at the bottom of the shaft which are compatible with those in the hydrant being retrofitted.

Stainless-steel spring

The stainless-steel spring shall fit around the shaft and free float on the valve on one extremity and attach to the hydrant bonnet on the other so that adequate pressure is placed on the valve to provide an impenetrable seal when the hydrant is not in use. The spring shall allow for water flow to open the valve and shall close the valve prior to the occurrence of any negative pressure.

Insert seat

The insert seat of the device shall be a ethylene propylene diene M-class rubber (EPDM)/powder coated steel sleeve inserted into the top of the hydrant barrel at the traffic breakaway allowing the seat for the valve to be positioned not less than one-half inch (1/2”) nor more than one-inch (1”) below the lowest nozzle outlet of the hydrant. The insert seat shall be machined to provide a venturi shape so as to minimize loss of water flow through the hydrant. The top of the insert seat shall have a machined seat to accommodate an EPDM chloramine-resistant quad-ring gasket which will provide an impenetrable seal between the insert seat and the valve. Insert seat diameter shall be sized to fit each individual model of hydrant.

Valve

The valve of the device shall be forged of bronze and machined to fit the barrel size of each individual hydrant model. The valve shall be a hat-shaped device with flange which seals on the EPDM quad-ring gasket of the insert seat. The valve shall be attached to the stainless steel stem in such a manner as to provide free vertical movement along the shaft. The seal between the valve and the shaft shall be provided by a Viton O-ring. The top of the valve shall provide a recess to accept the stainless-steel spring. This recess shall be deep enough to allow the valve, when in the up position, to travel high enough that it does not obstruct the flow of water through the hydrant. The retrofit device shall meet the American Water Works Association’s {AWWA} Standard C502 for dry barrel fire hydrants and AWWA subparagraphs1.1, 3.1.1,4.2.2.1, and 5.1 for backflow prevention. The retrofit device shall install on existing hydrants with no expensive excavation. The device shall show no loss of water flow for fire fighting and no negative effect on any hydrant function, including weeping. The retrofit device shall have been tested showing it is effective at preventing backflow into the water system at pressures up to 350 psi.

Appendix B: Fire Hydrant Performance Characteristics

DPW Location	Hydrant Make/Model	Hydrant Year	Physical Location	Torque (ft-lbs)		Flow (GPM)		Static Pressure (psi)		Stem
				Before	After	Before	After	Before	After	
4000/40	Muller Standard	1968	Behind Thader Elem	INOP	38	-	1000	-	74	304 SS
4000/43	Muller Standard	1965	Acrross from school	-	40	-	920	-	74	304 SS
4000/44	Muller Standard	1960	4261-B Williams St.	INOP	40	-	1060	-	70	304 SS
4000/45	Muller Standard	1960	4265-B Williams St.	INOP	40	-	1200	-	74	304 SS
4000/46	Muller Standard	1960	4269-B Williams St.	160		1150	1180	79	79	304 SS
4000/47	Muller Standard	1960	4200-B Thayer	INOP	40	-	1060	-	60	304 SS
4000/48	Muller Standard	1960	4206-A Thayer	80	30		1000	60	60	304 SS
4000/49	Muller Standard	1960	4243-A Williams St	INOP	50	-	1000	-	70	304 SS
4000/52	Muller Standard	1960	4212 Thayer	180	28		840	60	60	304 SS
4000/53	Muller Standard	1960	4228-B Thayer Ct	90	35	750	750	60	60	304 SS
4000/55	Muller Standard	1960	4238-A Thayer	160	40	650	650	68	60	Cold Rolled
4000/64	Muller Standard	1959	107 Wheeler St	INOP	38	-	1060	-	62	304 SS
4000/66	Muller Standard	1980	121 Wheeler St	230	40	980	1000	46	58	304 SS
4000/68	Muller Standard	1980	104 Toften St	INOP	38	-	800	-	44	304 SS
4000/70	Muller Standard	1960	114 Toften St	INOP	35	-	1050	-	60	304 SS
4000/72	Muller Standard	1960	210 Toften St	INOP	40	-	920	-	68	304 SS
4000/76	Muller Standard	1960	132 Humphrey St.	INOP	30	-	1000	-	76	304 SS
4000/79	Muller Standard	1960	Corner of Swift & H	INOP	35	-	1050	-	62	304 SS
4000/83	Muller Standard	1960	4458-B Swift St.	INOP	35	-	1000	-	60	304 SS
4000/85	Muller Standard	1960	100 Humphrey St	100	35	920	920	48	48	316
4000/88	Muller Standard	1965	Stugris St.	190	40	530	900	60	60	304 SS
4000/89	Muller Standard	1965	Sturgis St.	INOP	30	-	540	-	60	304 SS
4000/90	Muller Standard	1965	Sturgis St.	INOP	40	-	900	-	62	304 SS
4000/91	Muller Standard	1965	4102 Sturgis St.	INOP	40	-	920	-	62	304 SS
4000/92	Muller Standard	1965	4102 Sturgis St.	170	30	870	890	60	60	304 SS
4000/93	Muller Standard	1965	4104 Sturgis St.	INOP	35	-	910	-	64	304 SS
4000/94	Muller Standard	1965	4108 Sturgis St.	INOP	27	-	870	-	64	304 SS

DPW Location	Hydrant Make/Model	ydrant Ye	Physical Location	Torque (ft-lbs)		Flow (GPM)		Static Pressure (psi)		Stem
				Before	After	Before	After	Before	After	
1700-1	Kennedy K-10	1979	NE Corner of bldg 1	50	35	920	1060	59	59	304 SS
1700-7	Kennedy K-10	1979	East side of Bldg 17	120	48	1025	1000	59	59	304 SS
1700-19	Kennedy K-10	1979	SE ccorner of Bldg 1	45	45	1060	1150	66	66	304 SS
1700-27	Kennedy K-10	1979	SW corner of Bldg 1	75	45	920	920	60	60	Cold Rolled
300-1	Kennedy K-10	1979	Corner of Missouri a	50	50	1000	1100	50	50	304 SS
300-22	Kennedy K-10	1979	Illinois Ave	50	55	1130	1150	64	64	304 SS
300-27	Kennedy K-10	1979	Corner of 3rd and Il	-	70	-	1320	-	78	316
2100-14	Kennedy K-10	1979	Lousiana Ave			1060	1060	68	68	304 SS
2100-15	Kennedy K-10	1979	Lousiana Ave	60	35	940	960	62	62	304 SS
2200-1	Kennedy K-10	1979	Corner of 1st and M	65	50	880	920	58	58	304 SS
2200-2	Kennedy K-10	1979	Front of Bldg 2224	64	60	860	900	70	70	304 SS
2200-4	Kennedy K-10	1979	NW corner of Bldg 2	90	47	840	960	58	58	304 SS
2200-5	Kennedy K-10	1979	NW corner of Bldg 2	65	40	880	950	64	64	304 SS
2200-6	Kennedy K-10	1979	SE ccorner of Bldg 2	60	70	830	920	60	60	304 SS
2200-7	Kennedy K-10	1979	Corner of Bldg 2216	25	35	850	940	64	64	304 SS
2200-8	Kennedy K-10	1979	Corner of Bldg 2215	55	40	800	920	64	64	304 SS
2300-1	Kennedy K-10	1979	2352 1st St	55	45	950	1000	61	61	304 SS
2300-4	Kennedy K-10	1979	Corner of E. 2nd St	100	55	900	920	58	58	304 SS
2300-5	Kennedy K-10	1979	2445 Louisiana Ave.	55	44	920	920	68	68	304 SS
2300-6	Kennedy K-10	1979	2444 Louisiana Ave.	55	38	800	920	66	66	304 SS
2300-7	Kennedy K-10	1979	2442 Louisiana Ave.	60	55	920	920	58	58	304 SS
2300-8	Kennedy K-10	1979	2440 Louisiana Ave.	85	57	820	920	58	58	304 SS
2300-9	Kennedy K-10	1979	corner of Quarterm	60	40	880	970	58	58	304 SS
2300-12	Kennedy K-10	1979	2325 Quartermaste	90	50	920	870	58	58	304 SS
2300-13	Kennedy K-10	1979	2324 Quartermaste	65	50	940	880	58	58	304 SS
2300-19	Kennedy K-10	1979	2310 Railroad St.	40	25	840	920	56	56	304 SS
2300-22	Kennedy K-10	1979	2314 Railroad St	75	50	840	920	54	54	304 SS
2300-23	Kennedy K-10	1979	2318 Railroad St.	60	65	840	840	58	56	304 SS

DPW Location	Hydrant Make/Model	ydrant Ye	Physical Location	Torque (ft-lbs)		Flow (GPM)		Static Pressure (psi)		Stem
				Before	After	Before	After	Before	After	
1000-67	Muller INS	1980	Bldg 5400	35	34	1000	1000	50	50	304 SS
1000-68	Muller INS	1980	5400 Nebraska	35	35	1050	1060	65	65	304 SS
1700-2	Muller INS	1975	Bldg 1704	INOP	INOP	INOP	INOP	INOP	INOP	316
1700-3	Muller INS	1975	Bldg 1703			1060		60	60	304 SS
1700-4	Muller INS	1975	1700 8th St	90	55	1080	1100	60	60	304 SS
1700-5	Muller INS	1975	Bldg 1707	75	60	1130	1130	68	68	304 SS
1700-6	Muller INS	1975	Bldg 1703	55		1130		62	62	304 SS
1700-8	Muller INS	1975	Bldg 1714	INOP	50	-	1190	-	70	304 SS
1700-9	Muller INS	1975	Bldg 1711	75	70	830	830	66	66	304 SS
1700-13	Muller INS	1975	Bldg 1732 & 1733	100	50	1190	1190	70	68	304 SS
1700-15	Muller INS	1975	Bldg 1728 &1729	INOP	50	-	1150	-	70	304 SS
1700-16	Muller INS	1975	Bldg 1720 & 1724	130		1120		70	70	304 SS
1700-18	Muller INS	1975	Bldg 1762 & 1750	65	50	1100	1130	70	70	304 SS
1700-20	Muller INS	1975	Bldg 1765 & 1763	INOP	60	-	1130	-	50	304 SS
1700-25	Muller INS	1975	1740 Michigan St	110	35	1060	1150	60	60	304 SS

DPW Location	Hydrant Make/Model	ydrant Ye	Physical Location	Torque (ft-lbs)		Flow (GPM)		Static Pressure (psi)		Stem
				Before	After	Before	After	Before	After	
4000-41	Muller Centurion									Teflon
300-28	Muller Centurion	1987	Corner of 3rd and Il	40	35	1200	1250	70	70	304 SS
600-36	Muller Centurion	1994	615 Replacement A	45	25	1150	1190	64	64	304 SS
600-40	Muller Centurion	1994	615 Replacement A	25	30	1150	1190	64	64	304 SS
1000-37	Muller Centurion	1991	1000 S Dakots St	110	40	920	1000	50	50	304 SS
1700-10	Muller Centurion	1997	SE corner Bldg 1702	50	35	1080	1130	68	68	304 SS
2300-3	Muller Centurion	1991	2350 Louisiana St	35	35	900	880	68	68	304 SS
2300-20	Muller Centurion	1991	2311 Railroad St	35	30	1000	1050	58	58	316
4000-75	Muller Centurion	1992	130 Totten St	45	60	1040	1100	80	78	304 SS
4000-97	Muller Centurion	1991	4115 Piney Hills Dr,	60	45	1130	1180	64	64	304 SS
4000-98	Muller Centurion	1991	Piney Hills	65	45	1200	1230	64	64	304 SS

DPW Location	Hydrant Make/Model	ydrant Ye	Physical Location	Torque (ft-lbs)		Flow (GPM)		Static Pressure (psi)		Stem
				Before	After	Before	After	Before	After	
400-2	Clow Medallion	1994	NE Corner of Bldg 4	50	40	1000	1050	46	46	316
400-4	Clow Medallion	1994	NW Corner of Bldg 4	30	30	1040	920	48	48	304 SS
400-5	Clow Medallion	1994	SW Corner of Bldg 4	65	30	250	58	250	58	304 SS
400-30	Clow Medallion	1994	SE Corner of Bldg 47	45	25	1040	1030	58	55	304 SS
1700-12	Clow Medallion	2007	1734 Michigan Ave	50	40	1100	1130	70	70	304 SS
7000-177	Clow Medallion	2007		45		1190		64		304 SS

DPW Location	Hydrant Make/Model	ydrant Ye	Physical Location	Torque (ft-lbs)		Flow (GPM)		Static Pressure (psi)		
				Before	After	Before	After	Before	After	
300-2	American Foundry	1962	Missouri Ave Hospit	100	45	1120	1040	62	62	304 SS
300-3	American Foundry	1964	Missouri Ave Hospit	30	30	1060	1060	59	59	304 SS
1700-22	American Foundry	1962	1772 Michigan St.	110	100	1100	1100	60	60	304 SS
1000-38	American Foundry	1967	1021 Artillery Circle	75	35	850	840	50	50	304 SS
4000-86	American Foundry	1972	4110 Piney Hills Dr.	45	25	1020	1060	60	60	304 SS
4000-96	American Foundry	1972	4114 Piney Hills Dr.	65	55	1080	1000	68	68	316

Appendix C: Water Chemistry Analysis

Table C1. Water chemistry results.

	0 days	183 days	405 days
Conductivity [µS]	162	365	223
Ca Hardness [ppm as CaCO3]	75	92	57
Ca + Mg Hardness [ppm as CaCO3]	149	178	106
Total Alkalinity [ppm as CaCO3]	246	294	176
Bicorbonate Alkalinity [ppm as CaCO3]	246	294	176
Carbonate Alkalinity [ppm as CaCO3]	0	0	0
Cu [ppm]	<0.2	<0.2	<0.2
Zn [ppm]	<0.2	<0.2	<0.2
Cl [ppm]	9	8	12
Ca [ppm]	30	37	23
Mg [ppm]	18	21	12
SiO2 [ppm]	5	9	10
pH [pH units]	7.1	7.2	7.2

Table C2. Conductivity/Total Dissolved Solids conversions.

Conductivity (micro-mho/cm)	TDS (mg/L as $CaCO_3$)
1	0.42
10.6	4.2
21.2	8.5
42.4	17
63.7	25.5
84.8	34
106	42.5
127.3	51
148.5	59.5
169.6	68
190.8	76.5
212	85
410	170
610	255
812	340
1008	425

Figure C1. Linear regresson conversions.

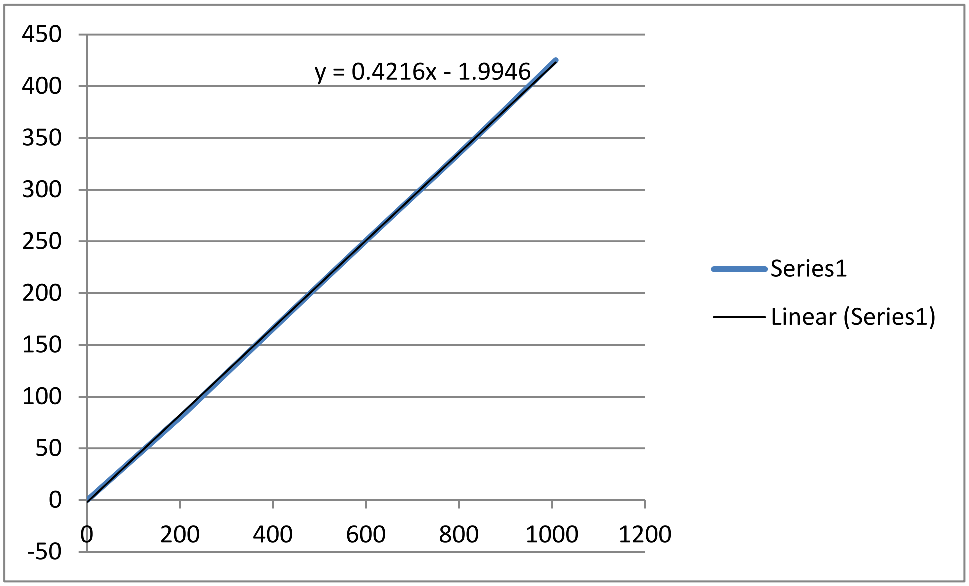


Table C3. Langelier saturation index calculations.

	0 days	183 days	405 days
Total Dissolved Solids	66.3046	151.8894	92.0222
Temperature (°C)	25	25	25
A = (Log10 [TDS] - 1) / 10	0.182154366	0.218153	0.196389261
B = -13.12 x Log10 (°C + 273) + 34.55	2.088282615	2.088283	2.088282615
C = Log10 [Ca2+ as CaCO3] - 0.4	1.475061263	1.563788	1.355874856
D = Log10 [alkalinity as CaCO3]	2.390935107	2.468347	2.245512668
Langelier Saturation Index	-0.60444061	-0.3743	-0.78328435

APPLIED TECHNICAL SERVICES, INCORPORATED

1049 Triad Court, Marietta, Georgia 30062 • (770) 423-1400 Fax (770) 424-6415

CHEMICAL TEST REPORT

Ref. C151296 **Date** April 14, 2010 **Page** 1 **of** 2

Customer: Mandaree Enterprises Corporation, 812 Park Drive, Warner Robins, GA 31088

Murphy, NC 28906-6864 Attention: Darrell Skinner

Purchase Order #: 2010-027 Part #/Name: Water Sample-Ft. Leonard Wood

Material Designation: Water

Special Requirement: N/A

Lab Comment: Analyzed by ICP atomic emission, electrometric and calculation techniques.

Test Results

Composition: (See Below)

Identification	Conductivity	pH	Ca Hardness	Ca + Mg Hardness
Spec. or Alloy ID	(1)	(1)	(1)	(1)
Sample	162 µS	7.1 pH units	75 ppm as $CaCO_3$	149 ppm as $CaCO_3$

Identification	Cl	Ca	Mg	Cu	Zn	SiO_2
Spec. or Alloy ID	(1)	(1)	(1)	(1)	(1)	(1)
Sample	9 ppm	30 ppm	18 ppm	<0.2 ppm	<0.2 ppm	5 ppm[(2)]

(1) None Supplied
(2) Calculated from silicon content

ISO 9001

Prepared by: W. M. Katter
Senior Chemist

Approved by: D. M. McKay
Supervisor

ATS300, 01/2010

APPLIED TECHNICAL SERVICES, INCORPORATED

1049 Triad Court, Marietta, Georgia 30062 • (770) 423-1400 Fax (770) 424-6415

CHEMICAL TEST REPORT

Ref. C151296 **Date** April 14, 2010 **Page** 2 **of** 2

Customer: Mandaree Enterprises Corporation, 812 Park Drive, Warner Robins, GA 31088
Murphy, NC 28906-6864 Attention: Darrell Skinner

Purchase Order #: 2010-027 Part #/Name: Water Sample-Ft. Leonard Wood

Material Designation: Water

Special Requirement: N/A

Lab Comment: Analyzed by titrimetric, electrometric and calculation techniques.

Test Results

Composition: (milligram per liter)

Identification	Total Alkalinity	Bicarbonate Alkalinity	Carbonate Alkalinity
Spec. or Alloy ID	(1)	(1)	(1)
Sample	246 ppm as $CaCO_3$	246 ppm as $CaCO_3$	0 ppm as $CaCO_3$

(1) None Supplied

ISO 9001

Prepared by: W. M. Katter
Senior Chemist

Approved by: D. M. McKay
Supervisor

ATS300, 01/2010

APPLIED TECHNICAL SERVICES, INCORPORATED

1049 Triad Court, Marietta, Georgia 30062 • (770) 423-1400 Fax (770) 424-6415

CHEMICAL TEST REPORT

Ref. C158482 **Date** October 15, 2010 **Page** 1 **of** 2

Customer: Mandaree Enterprises Corporation, 812 Park Drive, Warner Robins, GA 31088
Murphy, NC 28906-6864 Attention: Darrell Skinner

Purchase Order #: 2010-070 Part #/Name: Water Sample-10/8/10

Material Designation: Water

Special Requirement: N/A

Lab Comment: Analyzed by ICP atomic emission, electrometric and calculation techniques.

Test Results

Composition: (See Below)

Identification	Conductivity	pH	Ca Hardness	Ca + Mg Hardness
Spec. or Alloy ID	(1)	(1)	(1)	(1)
Sample	365 µS	7.2 pH units	92 ppm as $CaCO_3$	178 ppm as $CaCO_3$

Identification	Cl	Ca	Mg	Cu	Zn	SiO_2
Spec. or Alloy ID	(1)	(1)	(1)	(1)	(1)	(1)
Sample	8 ppm	37 ppm	21 ppm	<0.2 ppm	<0.2 ppm	9 ppm(2)

(1) None Supplied
(2) Calculated from silicon content

ISO 9001

Prepared by: J. Burmeister
Chemist

Approved by: W. M. Katter
Senior Chemist

ATS300, 05/2010

APPLIED TECHNICAL SERVICES, INCORPORATED

1049 Triad Court, Marietta, Georgia 30062 • (770) 423-1400 Fax (770) 424-6415

CHEMICAL TEST REPORT

Ref. C158482 **Date** October 15, 2010 **Page** 2 **of** 2

Customer: Mandaree Enterprises Corporation, 812 Park Drive, Warner Robins, GA 31088
Murphy, NC 28906-6864 Attention: Darrell Skinner

Purchase Order #: 2010-070 Part #/Name: Water Sample-10/8/10

Material Designation: Water

Special Requirement: N/A

Lab Comment: Analyzed by titrimetric, electrometric and calculation techniques.

Test Results

Composition: (milligrams per liter)

Identification	Total Alkalinity	Bicarbonate Alkalinity	Carbonate Alkalinity
Spec. or Alloy ID	(1)	(1)	(1)
Sample	294 ppm as $CaCO_3$	294 ppm as $CaCO_3$	0 ppm as $CaCO_3$

(1) None Supplied

ISO 9001

Prepared by: J. Burmeister
Chemist

Approved by: W. M. Katter
Senior Chemist

ATS300, 05/2010

APPLIED TECHNICAL SERVICES, INCORPORATED

1049 Triad Court, Marietta, Georgia 30062 • (770) 423-1400 Fax (770) 424-6415

CHEMICAL TEST REPORT

Ref. C167531 **Date** May 24, 2011 **Page** 1 **of** 2

Customer: Mandaree Enterprises Corporation, 812 Park Drive, Warner Robins, GA 31088

Attention: Darrell Skinner

Purchase Order #: 2011-022 Part #/Name: Water Sample (rec. 5/17/11)

Material Designation: Water (Fort Leonard Wood)

Special Requirement: N/A

Lab Comment: Analyzed by ICP atomic emission, electrometric and calculation techniques.

Test Results

Composition: (See Below)

Identification	Conductivity	pH	Ca Hardness	Ca + Mg Hardness
Spec. or Alloy ID	(1)	(1)	(1)	(1)
Sample	223 µS	7.2 pH units	57 ppm as $CaCO_3$	106 ppm as $CaCO_3$

Identification	Cl	Ca	Mg	Cu	Zn	SiO_2
Spec. or Alloy ID	(1)	(1)	(1)	(1)	(1)	(1)
Sample	12 ppm	23 ppm	12 ppm	<0.2 ppm	<0.2 ppm	10 ppm(2)

(1) None Supplied
(2) Calculated from silicon content

ISO 9001

Prepared by: W. M. Katter, Senior Chemist

Approved by: D. M. McKay, Supervisor

This report may not be reproduced except in full without the written approval of ATS. This report represents interpretation of the results obtained from the test specimen and is not to be construed as a guarantee or warranty of the condition of the entire material lot. If the method used is a customer provided, non-standard test method, ATS does not assume responsibility for validation of the method. Measurement uncertainty available upon request where applicable.

ATS300, 05/2010

APPLIED TECHNICAL SERVICES, INCORPORATED

1049 Triad Court, Marietta, Georgia 30062 • (770) 423-1400 Fax (770) 424-6415

CHEMICAL TEST REPORT

Ref. C167531 **Date** May 24, 2011 **Page** 2 **of** 2

Customer: Mandaree Enterprises Corporation, 812 Park Drive, Warner Robins, GA 31088
Murphy, NC 28906-6864 Attention: Darrell Skinner

Purchase Order #: 2011-022 Part #/Name: Water Sample (rec. 5/17/11)

Material Designation: Water (Fort Leonard Wood)

Special Requirement: N/A

Lab Comment: Analyzed by titrimetric, electrometric and calculation techniques.

Test Results

Composition: (milligram per liter)

Identification	Total Alkalinity	Bicarbonate Alkalinity	Carbonate Alkalinity
Spec. or Alloy ID	(1)	(1)	(1)
Sample	176 ppm as $CaCO_3$	176 ppm as $CaCO_3$	0 ppm as $CaCO_3$

(1) None Supplied

ISO 9001

Prepared by: W. M. Katter, Senior Chemist

Approved by: D. M. McKay, Supervisor

ATS300, 05/2010

Appendix D: Analysis Results for Copper Sleeve Bulge on Fire Hydrant Valve Stem

Background

The valve stems used in fire hydrants are made of carbon steel. They are connected to the valve on one end and are threaded at the other. At the base of the threads is a copper sleeve that is in contact with the o-ring seal of the stem body. The copper is used to provide a smooth surface that doesn't corrode and will allow the o-rings to slide smoothly over the surface when the valve is opened or closed. It is held in place by crimping the end into a groove machined into the steel stem. Underneath the sleeve is placed an o-ring seal in a groove approximately ¾ inch above the crimped seal. During the course of the stem's lifetime the copper sleeve will sometimes bulge as much as 1/8 inch at a location about 1 ¼ inch above the crimped end. This bulge prevents the valve from being opened completely, which causes other problems in the system. The task was to analyze the failure mechanism and provide a report.

Objective

The objective of this work is to determine the cause of the bulge in copper sleeve on the valve stem.

Experimental procedure

Figure D1 shows the valve stem as received. The bulge increased the diameter by 0.08 in. from its original diameter of 1.2 in. The copper was slit using a 4 in. angle grinder. The two halves were inspected and photographed. No evidence of corrosion of the copper was observed. Figure D2 shows the interior of the copper sleeve. When the sleeve was removed from the pipe, there was black powder underneath the copper. The powder was collected and mounted on a specimen holder for scanning electron microscope (SEM) analysis. The black powder was removed from the surface of the stem, and the surface was then inspected and photographed.

Results and discussion

Figure D3 shows the surface of the stem before the removal of the black powder. When the sleeve was slit and removed, a lot of the powder fell off. Figure D4 shows the stem after the black powder was removed. There is evidence of general corrosion, but the progress is such that the surface structure is not yet removed. Outlines can be seen where corrosion has progressed further on the surface. The interior surface (see Figure D2) is minimally affected by the corrosion process, with only some surface staining where the black powder was in contact.

The collected black powder was found to be magnetic. A sample was mounted on a specimen holder for the SEM. The surface chemistry of the powder was analyzed in and x-ray energy analyzer mounted on the SEM. The powder was put into the chamber, and the chamber was evacuated. Electrons were directed at the surface of the powder, and the resulting x-rays were measured and the energy signature analyzed to identify the elements present in the powder. Figure D5 is a photomicrograph of the powder at 85x magnification showing the uniformity of the granules. Figure D6 shows a plot of the counts versus energy for the measured x-rays. Analysis indicated that iron, oxygen, sulfur, chromium, manganese, and copper are present in the powder. A quantitative analysis of the data showed that the iron to oxygen atomic ratio is approximately 1:1, indicating that the black powder is mostly FeO, which is magnetic. The x-ray energy analysis results are shown in Table D1.

The results of all observations and analyses indicate that the bulge is caused by dissimilar-metals corrosion promoted by moisture trapped between the copper sleeve and the shaft of the valve stem. The rubber o-ring under the sleeve effectively holds the water, and the resulting corrosion causes the copper to bulge at this location as corrosion products accumulate. The volume increase due to corrosion is fourfold over the unaffected metal. The water could be entering this space from the top, around the shaft during rainstorms; or it could be condensing onto the metal parts due to humidity; or it may seep in from the pressurized water system below the water system below.

Conclusions and recommendations

It is concluded that water becomes trapped between the copper sleeve and the steel valve stem shaft. This moisture and the close proximity of dissimilar metals caused localized corrosion in the affected area. The increase in volume of the corrosion product caused the copper sleeve to bulge in places where corrosion products accumulated on the steel shaft. In order to stop this type of corrosion in a valve stem of this design, the assembly must be sealed against intrusion of moisture between the copper sleeve and steel stem. If freezing contributed to the bulge, the solution to that problem also would require keeping moisture out of the affected area.

Figure D1. Fire hydrant valve stem showing bulge in copper sleeve.

Figure 2. Interior of copper sleeve showing marks from interior o-ring and some residue of iron oxide.

Figure 3. Surface of the valve stem
showing buildup of black powder on right side of o-ring.

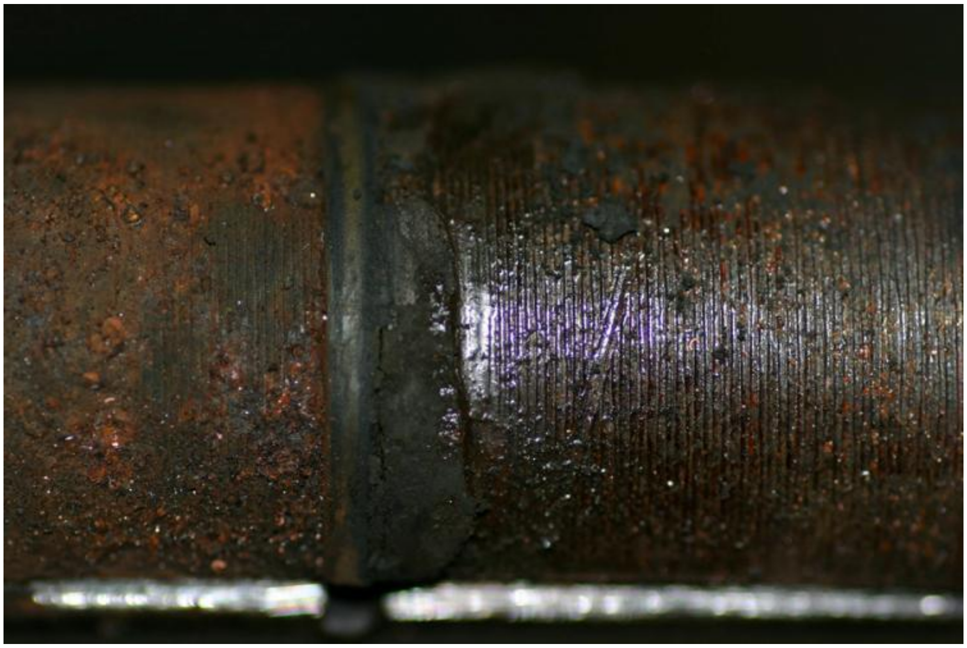


Figure D4. Valve stem after removal of black powder
showing area of corrosion attack.

Figure D5. SEM photomicrograph of black powder (85x magnification).

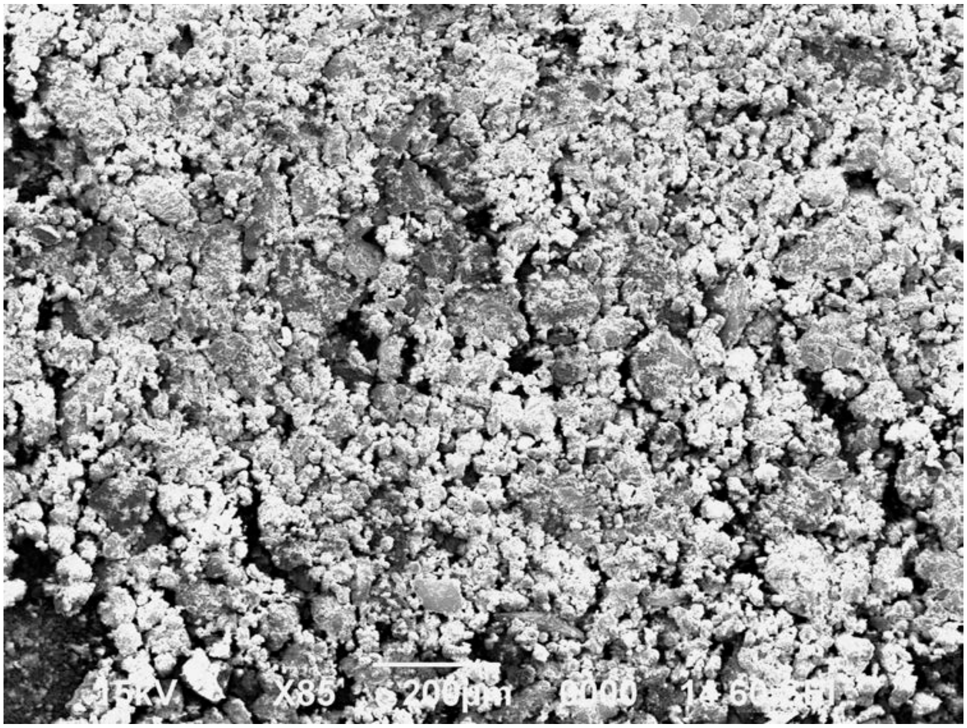


Figure D6. Plot of counts versus x-ray energy for the black powder from the valve stem under the copper sleeve.

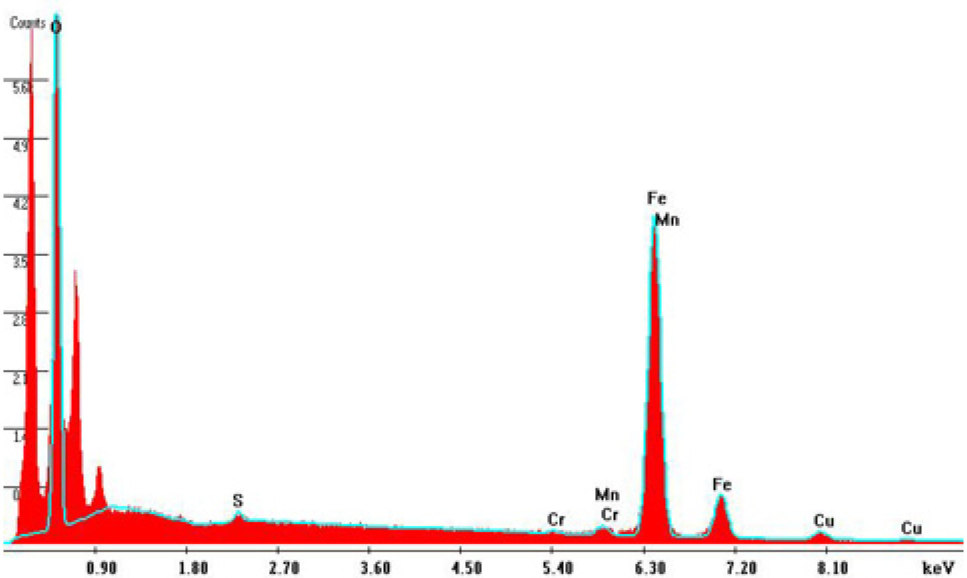


Table D1. Quantitative analysis of the black powder from fire hydrant.

Time : 15:20:18 Date:16-Mar-2011						
Weight % by Element						
	O K	S K	CrK	MnK	FeK	CuK
	20.60	0.38	0.28	1.60	72.68	4.46
Atomic % by Element						
	O K	S K	CrK	MnK	FeK	CuK
	47.59	0.44	0.20	1.07	48.10	2.60
K-Ratio						
	O K	S K	CrK	MnK	FeK	CuK
	0.1369	0.0034	0.0033	0.0150	0.6991	0.0398
Matrix Corrections						
	Method		O K			
	ZAF	1.1381	0.5823	1.0029		
			S K			
		1.0772	0.8145	1.0030		
			CrK			
		0.9570	0.9975	1.2398		
			MnK			
		0.9392	1.0003	1.0028		
			FeK			
		0.9562	1.0018	1.0042		
			CuK			
		0.9222	0.9681	1.0000		

Net Intensities						
	O K	S K	CrK	MnK	FeK	CuK
	234.80	4.87	1.61	6.09	229.83	6.13
Background Intensities						
	O K	S K	CrK	MnK	FeK	CuK
	6.96	12.69	8.28	6.90	6.07	3.48
Intensity Errors						
	O K	S K	CrK	MnK	FeK	CuK
	0.47	7.94	18.62	5.14	0.48	4.14

Appendix E: Implementation Guidance

Below are recommendations for additions to or revisions of applicable standards to promote implementation of DATV technology by the Army.

AWWA C502

4.6.5.4 Stem Nut. Stem nuts shall be made of a brass or copper alloy.

4.6.5.6 Hydrant Stem. The stem above the breakaway couple shall be made of stainless steel

4.8.3 *Backflow Valve*

4.8.3.1 Interface. When retrofitted the valve shall be prevent contamination of the water system either from back-flowing under pressure or contamination by siphoning into the water main. The valve must be stealth and passive requiring no action on the part of the fire department other than that normally required to activate the hydrant. The valve shall be maintenance-free and expose potable water to no new materials other than those currently approved for use in fire hydrants. The device shall withstand a backpressure of 350 psi without allowing an agent to enter the system.

4.8.3.2 Stainless-Steel Spring. The stainless-steel spring shall fit around the shaft and free float on the valve on one extremity and attach to the hydrant bonnet on the other so that adequate pressure is placed on the valve to provide an impenetrable seal when the hydrant is not in use. The spring shall allow for water flow to open the valve and shall close the valve prior to the occurrence of any negative pressure.

4.8.3.3 Insert Seat. The insert seat of the valve shall be made of a ethylene propylene diene M-class rubber (EPDM)/powder coated steel sleeve inserted into the top of the hydrant barrel at the traffic breakaway allowing the seat for the valve to be positioned not less than one-eighth inch (1/8”) nor more than one-inch (1”) below the lowest nozzle outlet of the hydrant. The insert seat shall be machined to provide a venturi shape so as to minimize loss of water flow through the hydrant. The top of the insert seat shall have a machined seat to accommodate an EPDM Chloramine resistant quad-ring gasket which will provide an impenetrable seal between the insert seat and the valve. Insert seat diameter shall be sized to fit each individual model of hydrant.

4.8.3.4 Valve. The valve shall be forged of bronze and machined to fit the barrel size of each individual hydrant model. The valve shall be a hat-shaped device with flange which seals on the EPDM quad-ring gasket of the insert seat. The valve shall be attached to the stainless steel stem in such a manner as to provide free vertical movement along the shaft. The seal between the valve and the shaft shall be provided by a Viton O-ring. The top of the valve shall provide a recess to accept the stainless-steel spring. This recess shall be deep enough to allow the valve, when in the up position, to travel high enough that it does not obstruct the flow of water through the hydrant.

NFPA 24

4-1.4 Dry-barrel hydrants shall be equipped with a backflow prevention valve which allows water to flow freely from the hydrant but prevents any substance from being pumped or siphoned into the water system via the hydrant. The check valve shall be located in the upper barrel of the hydrant (above grade) and be field serviceable without digging and capable of withstanding 350psi of back pressure without allowing backflow into the system. Check valve kit shall include a stainless steel operating stem, brass valve, stainless steel spring and corrosion proof sleeve.

UFC 3-600-01

3-7.3.3 Hydrant Protection. Hydrants located adjacent to parking areas or other vehicle traffic areas must be protected by bollards. The bollards must be located so they are not directly in front of an outlet. Dry-barrel hydrants shall be equipped with a backflow prevention valve which allows water to flow freely from the hydrant but prevents any substance from being pumped or siphoned into the water system via the hydrant. The installation must comply with the American Water Works Association Manual C502 *Dry-barrel Fire Hydrants*. The check valve shall be located in the upper barrel of the hydrant (above grade) and be field serviceable without digging and capable of withstanding 350psi of back pressure without allowing backflow into the system. Check valve kit shall include a stainless steel operating stem, brass valve, stainless steel spring and corrosion proof sleeve.

UFGS 33 11 0 0

2.1.2.7 Fire Hydrants

a. Dry-barrel hydrants shall be equipped with a backflow prevention valve which allows water to flow freely from the hydrant but prevents any substance from being pumped or siphoned into the water system via the hydrant [specified in AWWA C502]. The check valve shall be located in the upper barrel of the hydrant (above grade) and be field serviceable without digging and capable of withstanding 350psi of back pressure without allowing backflow into the system. Check valve kit shall include a stainless steel operating stem, brass valve, stainless steel spring and corrosion proof sleeve.

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. REPORT DATE (DD-MM-YYYY)
October 2013

2. REPORT TYPE
Final

3. DATES COVERED (From - To)

4. TITLE AND SUBTITLE
Demonstration of Corrosion-Resistant Fire Hydrant Retrofits For Military Installations

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER
Corrosion Prevention and Control

6. AUTHOR(S)
Edgar Dean Smith, Mark D. Ginsberg, and Clint Wilson

5d. PROJECT NUMBER
F09-AR12

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

US Army Engineer Research and Development Center
Construction Engineering Research Laboratory
P.O. Box 9005
Champaign, IL 61826-9005

8. PERFORMING ORGANIZATION REPORT NUMBER
ERDC/CERL TR-13-20

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Office of the Secretary of Defense (OUSD(AT&L))
3090 Defense Pentagon
Washington, DC 20301-3090

10. SPONSOR/MONITOR'S ACRONYM(S)
OSD

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

Most fire hydrants are operated rarely, but it is critical that they be fully functional when needed. Corrosion can severely damage hydrants internally without any visible indications. Inoperable hydrants present an unacceptable risk to Department of Defense personnel and property. This project demonstrated a corrosion-resistant retrofit kit for fire hydrants that includes an anti-backflow valve to prevent accidental or intentional water-supply contamination. The technology was installed on 90 fire hydrants of various makes, models, and ages at Fort Leonard Wood, MO. To evaluate hydrant performance before and after the retrofits, the researchers measured the torque needed to operate each hydrant, volumetric flow, and static pressure. After 12 months in service with the retrofits, a subset of the hydrants was opened for visual inspection of the corrosion-resistant replacement parts. In addition, water chemistry at the demonstration site was tested three times within a year for corrosivity and scaling tendencies, and microscopic studies were performed on a previously failed hydrant component to determine the cause of its shape deformation.

Visual evaluation of DATV components after approximately 12 months of service indicated that they provide excellent corrosion resistance. An economic analysis of the demonstration indicated a return on investment of 5.73.

15. SUBJECT TERMS

corrosion prevention, fire hydrants, retrofit, Fort Leonard Wood, MO

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			**19b. TELEPHONE NUMBER** (include area code)
Unclassified	Unclassified	Unclassified		63	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. 239.18